CHAPTER 4. DESCRIPTION OF COMPUTER SUBROUTINES FOR THE SNOW ACCUMULATION AND ABLATION MODEL

4.1 INTRODUCTION

This chapter describes the computer subroutines which are needed to use the snow accumulation and ablation model in conjunction with the NWSRFS. The NWSRFS programs, as described in HYDRO-14, contain all the statements that are needed to communicate with the snow subroutines, i.e., subroutine CALL statements, COMMON blocks, and initialization of variables. Snow subroutines are provided for all three NWSRFS programs involving hydrograph simulation; the verification program (NWSRFS4), the optimization program (NWSRFS3), and the operational river forecasting program (NWSRFS5).

4.2 SUBROUTINES

There are four snow subroutines for the verification program, three for the optimization program, and three for the operational river forecasting program. Following is a brief description of the function of each subroutine:

a. Subroutines included in the verification, optimization, and operational programs.

   1) SNOWPM inputs snow parameters and initial values of snowpack storages and variables for each sub-area for which channel inflow is to be computed. Soil-moisture accounting sub-areas and snowpack accounting sub-areas are identical. The subroutine also outputs the parameters and initial values for future reference.

   2) PACK is the subroutine that simulates the accumulation and ablation of the snowpack, as described in Chapter 3. As a reference for those readers who are interested in the snow accumulation and ablation model, but do not want to obtain all the NWSRFS programs, a listing of subroutine PACK, from the verification program, is contained in appendix C.

b. Subroutine included in the verification and optimization programs.

   SNOWIN inputs six-hour air temperature data from tape. In addition, observed daily water-equivalent of the snowpack can be input from tape if such data are available. Observed water-equivalent data are not used in the computations, but are printed out so that a visual check between observed and computed water-equivalent can be made. (Note. In using the data processing programs from appendix E of HYDRO-14 to load observed water-equivalent data onto tape, observed water equivalent is treated as if it were mean daily flow data. For example, if two observed water equivalent stations and four mean daily flow stations were being loaded, the data processing programs would be instructed to load six mean daily flow stations. The observed water-equivalent stations must be placed before the mean daily flow stations in the input queue.) All data are input a month at a time. All snow data must be on the same tape. The subroutine contains the flexibility that if more stations or areas are on tape than are needed for a particular run, only that information that is requested is read. Thus, one data tape can be set up for a large river system and be used for running any segment of the system.

c. Subroutine included in the verification program only.

SNOWOT is a short subroutine which outputs total monthly snowfall, rain, and snowpack outflow, plus a water balance of the snowpack as a check on PACK subroutine computations.

d. Subroutine included in the operational program only.

UPSNOW allows for the input of adjustments to snowpack parameters and variables which may be needed operationally to adjust the snow model so that simulated conditions agree with observed conditions. A description of the adjustments is included later in this chapter under section 4.5.3.

4.3 VERIFICATION SNOW SUBROUTINES

This section describes the options, input required, and output produced by the snow subroutines which are used in conjunction with the verification program (NWSRFS4).

4.3.1 SUBROUTINE OPTIONS

There are three optional features in regard to data input and computer output with the verification snow subroutines.

a. As mentioned previously, observed daily water-equivalent data can be input and printed for comparative purposes. If observed water-equivalent data are not available, which is usually the case, the input of such data are eliminated.

b. The verification program contains the flexibility that the snow subroutines do not have to be used every month. Thus, during months when there is no snowfall and no snow on the ground, the program can bypass the snow subroutines. This feature eliminates the need for valid air temperature data during non-snow months. Thus, during non-snow months the air temperature records on the basic data tape can be loaded as missing data. Missing air temperature data are signified by 999.0.

c. During calibration it is important in many cases to monitor daily changes in snowpack conditions. This is necessary to answer questions such as: Was the runoff caused by melt, rain on snow, or just rain? What is the areal extent of snow cover during a certain period? What is the amount of negative heat storage and liquid-water retention before a certain event? Was the precipitation assumed to be rain or snow? When did melt occur? When did the snowpack disappear? To answer such questions the subroutines contain the option that snowpack variables can be output on a daily basis for each sub-area.

4.3.2 INPUT SUMMARY

Appendix D.1 contains a listing of the input needed to run the verification program with snow included.

4.3.3 SAMPLE INPUT

Appendix D.2 lists the input for an eight-year run of the verification program on the Passumpsic River at Passumpsic, Vermont.

4.3.4 SAMPLE OUTPUT

Appendix D.3 lists examples of the output from the run of the verification program which used the sample input data for the Passumpsic River. To conserve space, the entire output is not listed, but only examples of each type of printout.

4.4 OPTIMIZATION SNOW SUBROUTINES

This section describes the options, input required and output produced by the snow subroutines which are used in conjunction with the optimization program (NWSRFS3).

4.4.1 SUBROUTINE OPTIONS

There are two options in regard to snow computations included in the optimization program. The standard options of the optimization program are described in chapter 7 of HYDRO-14.

a. As in the verification program, the program can be instructed to bypass the snow subroutines during months with no snowfall and no snow on the ground.

b. The optimization program can be used for either one or two snow and soil-moisture accounting sub-areas (see section 7.4.3 of HYDRO-14). As the optimization program is currently written, soil-moisture accounting parameters are the same for each area when two sub-areas are used. In the snow subroutines different parameter values can be used for each sub-area. The use of different parameter values for each sub-area is intended for use during the optimization of a mountain watershed with two elevation zones. Care should be exercised for two reasons if this option is used: 1) geographical factors which would suggest the use of different snow parameters for each area also would generally suggest the use of different soil-moisture accounting parameters, and 2) unless variables such as water-equivalent and areal snow cover are available for each sub-area as a check on simulation results, the addition of twice as many snow parameters may allow for an improved hydrograph simulation, but at the expense of an unreasonable simulation of snow accumulation and ablation within each area. A further discussion of the use of elevation zones in mountainous areas is contained in section 5.8.1.

4.4.2 INPUT SUMMARY

Appendix E.1 contains a listing of the input needed to run the optimization program with snow included.

4.4.3 SAMPLE INPUT AND OUTPUT FOR OPTIMIZATION RUN

Appendix E.2 lists the input and the output for an optimization run on the Passumpsic River at Passumpsic, Vermont.

4.4.4 SAMPLE INPUT AND OUTPUT FOR SENSITIVITY RUN

As described in chapter 7 of HYDRO-14, the optimization program can also be operated in a sensitivity mode. Appendix E.3 lists the input and output for a sensitivity run on the Passumpsic River.

4.5 OPERATIONAL SNOW SUBROUTINES

This section describes program features, input required, and the output produced by the snow subroutines which are used in conjunction with the operational river forecasting program (NWSRFS5).

4.5.1 INPUT OF AIR TEMPERATURE DATA

In the operational program all data are input through subroutine DATAIN (see section 6.2 of HYDRO-14). This includes the input of six-hour air temperature data; both air temperatures that have been observed and those that are predicted to occur in the future. The determination of six-hour mean areal air temperature from point observations and possibly other meteorological data is left to the user. Since each river forecast office has different data networks, it would be extremely difficult to write a generalized operational data processing program that would fit the needs of all forecast offices. Thus, the task of writing an operational data processing program (i.e., a program to compute mean areal precipitation from point observations or other meteorological data, compute an estimate of evapotranspiration, compute mean areal air temperature from point values and other meteorological data, and compute discharge from river stage observations or reservoir levels) is left to the user.

In the case of air temperature, the point should be made that data other than maximum-minimum temperature observations will be available on an operational basis to compute six-hour mean areal air temperature. There will also be more data available to delineate whether precipitation is rainfall or snowfall. However the number of air temperature observation stations available operationally may be considerably less than the number used for model calibration. The effect of the operational temperature data network on simulation results should be random, as long as there is not a significant bias between the operational mean areal air temperature estimation procedure and the mean areal temperature procedure used in calibration.

4.5.2 INCLUSION OF SNOW IN AN OPERATIONAL RUN

On each run of the operational program the user must tell the program if snow is to be included. If there is no snowfall and no snow on the ground, the snow subroutines are not needed. This feature not only saves computer time during non-snow periods, but also eliminates the need for observed and predicted mean areal air temperature data. Snow parameters and initial values are retained on the carryover tape (see section 6.6 of HYDRO-14) so that they are available when the next snowfall occurs. However, the user must remember to input snow parameters on the initial run of the operational program or on another run subsequent to the first occurrence of snow. Once snow parameters are input they will be retained for use whenever snow occurs.

4.5.3 SNOWPACK ADJUSTMENTS

Several snowpack variables and parameters can be adjusted so that simulated conditions will agree with observed conditions. These adjustments fall into two categories: 1) adjustments to make snowpack variables such as water-equivalent and areal extent of snow cover agree with observed values, and 2) adjustments to correct for deviations between the simulated and observed hydrographs. In making hydrograph adjustments a major consideration is to determine the most likely cause of the error so that the correction will minimize future deviations of the hydrographs. A set of decision rules to accomplish this is an area for considerable future research. For the present, the program supplies only the methods of adjusting; the hydrologist must decide which adjustment to use. The following snowpack adjustments are available.

a. Adjustments to snowpack variables.

   1) Areal water-equivalent can be adjusted at any time by reading in a new areal water-equivalent value for those sub-areas which are in error. New areal water-equivalent values will usually be based on field measurements of water-equivalent. However, in some cases, water-equivalent adjustments may be based on deviations between simulated and observed hydrographs. In the operational program the following rules are used for adjusting areal water-equivalent:

      a) The new value is input in terms of total water-equivalent, i.e., solid plus liquid-water content of the snowpack.

      b) The percent liquid-water in the new snowpack is the same as in the old one.

      c) Areal extent of snow cover remains the same.

Subroutine UPSNOW changes the solid and liquid portions of the snowpack so that the percent liquid-water remains the same. Subroutine UPSNOW also computes an adjustment factor (AWEADJ) which keeps the areal extent of snow cover (AESC) the same:

$$AWEADJ = \frac{AESC_1}{AESC_2}, \tag{4.1}$$

where: $AESC_1$ is the areal extent of snow cover computed from the basic areal depletion curve using the old value of areal water-equivalent, and $AESC_2$ is the areal extent of snow cover computed from the basic areal depletion curve using the new value of areal water-equivalent. (The basic areal depletion curve is the curve that was determined during model calibration.)

This adjustment factor remains in effect until the areal water-equivalent is adjusted again. The effect of AWEADJ is to temporarily shift the areal depletion curve. This effect is illustrated in figure 4.2.

2) Areal extent of snow cover can also be adjusted at any time by reading in a new value of areal snow cover for those sub-areas which are in error. Areal snow cover adjustments also will be based generally on observations of area snow cover, but could also be used to adjust the simulated hydrograph in some situations. Subroutine UPSNOW computes an adjustment factor (AEADJ) which temporarily shifts the areal depletion curve in a manner similar to AWEADJ:

$$AEADJ = \frac{AESC\ new}{AESC\ old} \tag{4.2}$$

This adjustment factor remains in effect until the areal extent of snow cover is adjusted again. The effect of AEADJ on the areal depletion curve is illustrated in figure 4-2. It should be noted that to remain on the basic areal depletion curve that both areal water-equivalent and areal extent of snow cover must be adjusted.

3) The gage catch deficiency factor (SCF) for snowfall varies from storm to storm primarily as a function of wind. Operationally, wind data may be available and thus the user may want to estimate SCF for each storm rather than use a mean catch deficiency factor for all storms. An adjusted value of SCF can be input for any or all sub-areas. The adjusted value of SCF is not retained for future use, but is used only for the present storm. The mean snowfall correction factor is retained on the carryover tape.

b. Adjustments to correct hydrograph deviations.

1) The volume of snowmelt can be adjusted by applying a multiplying factor to the computation of melt. Since melt is computed differently during rain on snow and non-rain periods, two adjustments are needed:

a) During non-rain periods the melt factor (M_f) can be multiplied by a correction factor.

b) During rain on snow events, the average wind function (UADJ) can be multiplied by a correction factor.

Both of these corrections are only applied to observed data. The corrections do not apply to the forecast period (future period for which predicted data are used). If several days of observed data are included in the computer run, the same multiplication factor applies to each day. The only method available to adjust different days by different amounts is to adjust the mean areal air temperature data.

2) The amount of negative heat storage can also be adjusted. This adjustment would probably not be used very often, but could be helpful during the early portion of snowmelt when the snowpack is becoming "ripe" and runoff is beginning to occur. The negative heat storage adjustment is also useful during mid-winter rain on snow events to partition the rain between that which is released and that which is retained within the snowpack. Even though negative heat storage is a snowpack variable, it is listed under hydrograph adjustments, since the adjustment to negative heat storage would almost always be based on deviations between observed and simulated hydrographs rather than on measurements of the variable itself.

4.5.4 INPUT SUMMARY

Appendix F.1 contains a listing of the input needed to run the operational river forecasting program with snow included.

4.5.5 SAMPLE INPUT AND OUTPUT FOR OPERATIONAL PROGRAM

Appendices F.2, F.3 and F.4 list the input and output for three runs of the operational program on the Rock River at Rock Rapids, Iowa. Appendix F.2 lists the initial run of the program to illustrate how to get the program started and how to create the initial carryover tape. Appendix F.3 shows the preliminary run on a major flood. Appendix F.4 illustrates the use of several adjustments to revise the preliminary run for the same major flood.

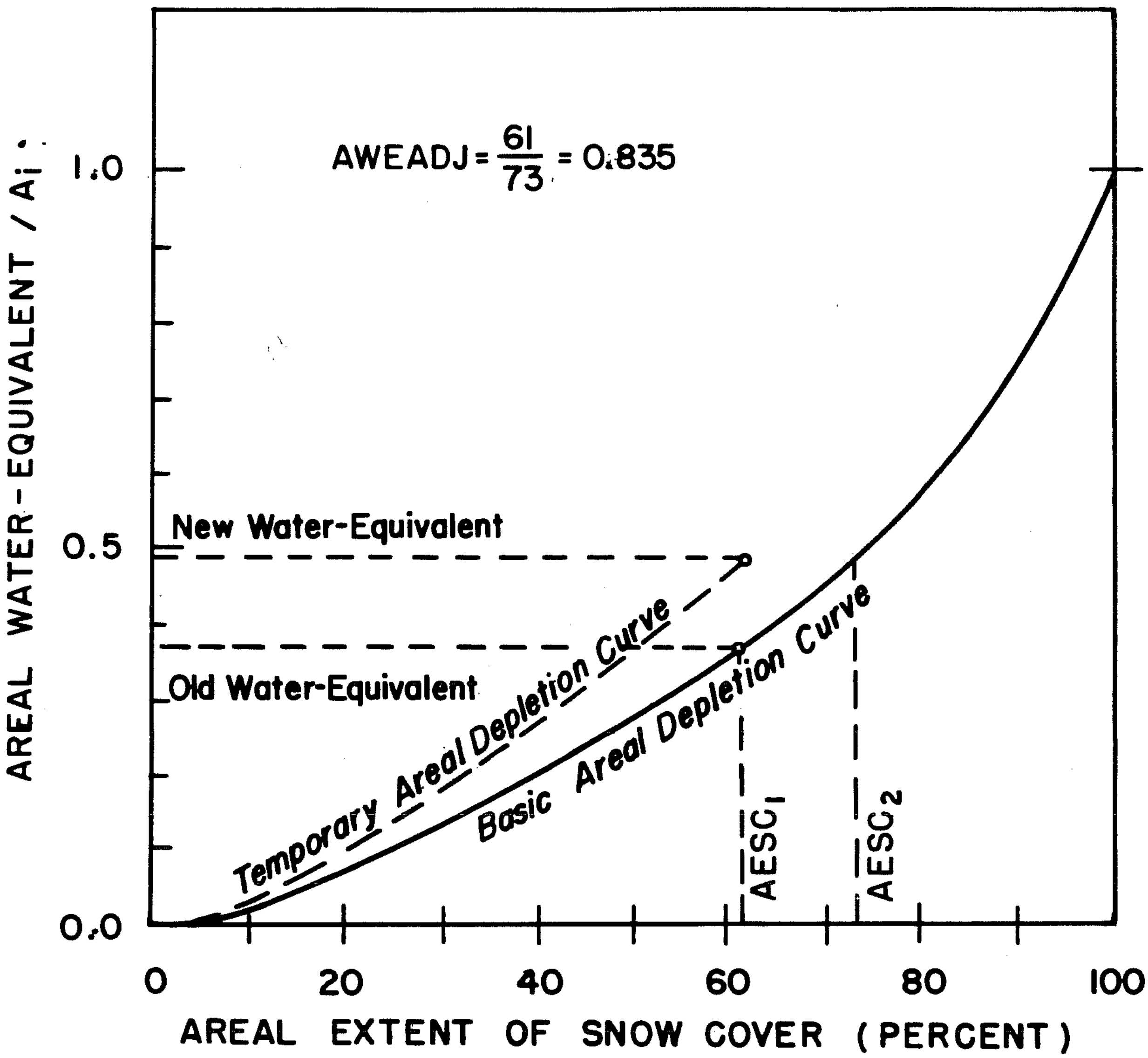

Figure 4-1. Effect of areal water-equivalent adjustment on the areal depletion curve.

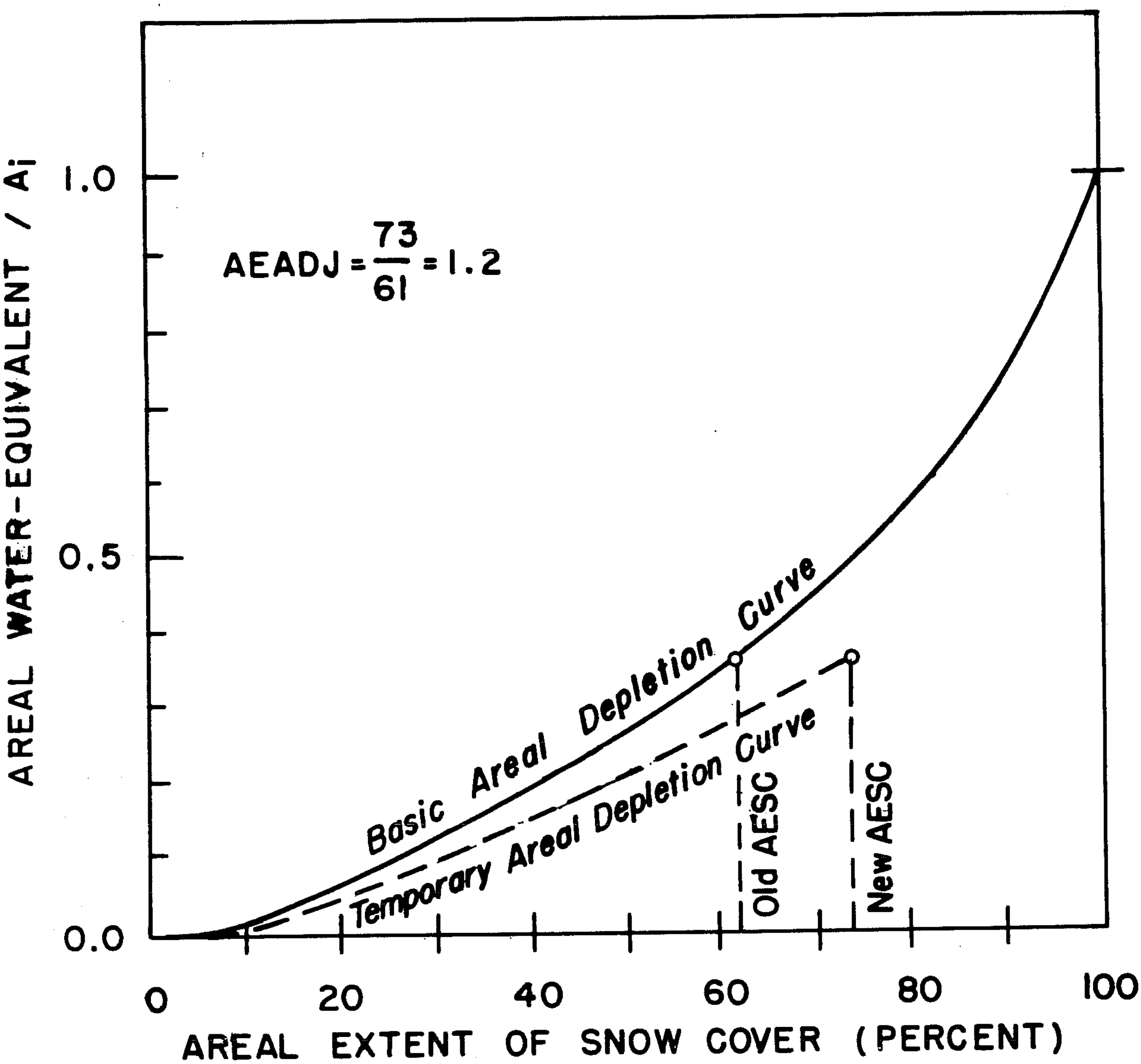

Figure 4-2.. Effect of areal extent of snow cover adjustment on the areal depletion curve.